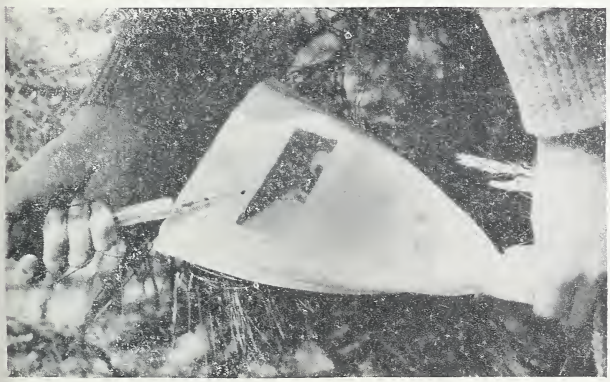
Historic, archived document

Do not assume content reflects current scientific knowledge, policies, or practices.

TREE BREEDING

at the Institute of Forest Genetics



FOREST SERVICE

UNITED STATES DEPARTMENT OF AGRICULTURE

Miscellaneous Publication No. 659

CONTENTS

	Page
History	1
Early problems	3
Pines chosen for study	3
Seed-tree studies	6
The hybrid program	6
Successful crosses made	7
Hybrid plantations planned	9
Related research	10
Elevation effects	10
Cuttings and grafting	10
Seed variation	11
Pollen storage	13
Outlook	13

Tree Breeding at the Institute of Forest Genetics

Prepared in the Forest Service

THE Institute of Forest Genetics is a field laboratory of the Forest Service, United States Department of Agriculture. It is operated by the California Forest and Range Experiment Station, which cooperates with and maintains headquarters at the University of California in Berkeley. The institute is a research organization devoted to the production of better forest trees by the use of genetic principles and breeding methods.

HISTORY

Like most human ventures, the Institute of Forest Genetics had its beginning as the rather nebulous idea of one man. James G. Eddy, a Seattle lumberman, knew the history of forest depletion in New England, in the Lake States, and in the South. He saw it being repeated during the early 1900's in the Pacific Northwest: First, an apparent overabundance of timber; next, the accelerating harvest of the forests; and finally, in many places a wasteland punctuated by stumps, burned snags, and too few young trees.

Mr. Eddy also knew that this same tragic course of events had been associated with the rise and decline of earlier civilizations in Palestine, Iran, North Africa, India, and China. No solution of the problem had been found in the past. Was a solution possible here? There was no doubt that the United States needed all the lumber being cut to maintain the Nation's growth. Yet our forests were not producing timber as fast as it was being used. Mr. Eddy realized that timber savings could and would be made by better cultural and harvesting methods, by more complete utilization of the trees, and by the introduction of substitutes for lumber. Even so, he feared that a timber shortage was inevitable unless some way could be devised to make forest land produce more timber.

Meanwhile the work of a horticulturist in Santa Rosa, Calif., was attracting world-wide attention. Luther Burbank was applying the skills and techniques of plant breeding to the practical production of flowers, fruits, and field crops. His results were impressive. Mr. Eddy decided to consult Burbank about the problems of forestry. Correspondence was followed by conversations at Santa Rosa. Skeptical at first, Mr. Burbank became enthusiastic over the possibilities for improving forest trees. He believed that fast-growing pines could be bred as successfully as giant daisies or high-yielding potato varieties. He encouraged Mr. Eddy to develop plans for a tree-breeding establishment.

793378°—48

In 1924 Mr. Eddy and Lloyd Austin, whom he employed to direct the work and who served in this capacity until 1940, sought a suitable location for the tree-breeding station. All of the milder timber-growing sections of the United States were considered, most of them being visited by Mr. Eddy or by Mr. Austin. They compared climatic data, soils, accessibility, and other important requisites for tree growing, and finally chose the vicinity of Placerville, Calif., for the work. On a site embracing 106 acres 3 miles east of the city, they established the Eddy Tree Breeding Station. Clearing of land and collecting of seed started in 1925.

The location has proved to be entirely satisfactory. Placerville, called Hangtown in the days of the gold rush, is a pleasant agricultural community with an atmosphere that belies its picturesque and sometimes turbulent history. Paved highways and roads link the tree-breeding station with the town and adjacent forests. Transcontinental U. S. Highway 50 passes through Placerville and in crossing the Sierra Nevada provides a general view of vegetation at elevations ranging from 200 to 7,000 feet above sea level. Along this route are 11 species of pine in natural stands, including ponderosa pine, Jeffrey pine, and sugar pine, the three principal timber pines of the West Coast. This mixed forest that clothes the Sierra Nevada has become the outdoor laboratory for much of the pine-breeding work.

Things went well with the Eddy Tree Breeding Station for several years. Seventy of the approximately 90 pine species of the world were planted in the arboretum, a research staff was assembled, large-scale selection of desirable trees was begun, and hybridizing was attempted in a limited way. In 1930 it was decided to incorporate the station under the name "Institute of Forest Genetics," to appoint a board of directors, and then to seek financial support for the work. During the several trying years that followed, in addition to funds supplied by Mr. Eddy, contributions and help were received

FIGURE 1.—Laboratory and part of the grounds at the Institute of Forest Genetics.

from the Carnegie Institution of Washington and the newly established Soil Erosion Service (later renamed the Soil Conservation Service).[1]

By gift, in 1935, the institute (fig. 1) became a part of the United States Forest Service, which has operated it since that time.

EARLY PROBLEMS

When tree-breeding work began, the staff had to decide certain fundamental issues that would influence the course of the work for many years. Should a limited group of trees be selected for experimentation or should an attempt be made to improve all of this country's timber trees? Should the first objective be wood quality, or growth rate or some other desirable attribute? Should the main effort be concentrated on improving the existing timber trees by selecting the best available strains or should the effort be directed primarily toward the production of new strains by hybridizing? These were among the questions vital to the long-range program that required an early answer.

Pines Chosen for Study

At first it seemed possible that several groups of trees might be investigated simultaneously. During the early years, in addition to acquiring all of the pine species available, a sizable planting of Douglas-fir was made, a collection of walnut varieties was planted at the California State Nursery near Davis, and numerous hardwood and coniferous species were set out as specimen trees on the grounds of the station. It soon became apparent, however, that any one of the groups of timber trees offered enough opportunities and problems to occupy the staff for many years. The pines were chosen for intensive work. They have continued as the center of research effort to the almost total exclusion of other plant groups.

Several characteristics of the pine group (genus *Pinus*) made it a logical selection which has been justified by subsequent results. The pines are distributed widely throughout the Northern Hemisphere. One species (*Pinus merkusii*) is found below the equator in the East Indies. There are in the neighborhood of a hundred species and well-marked varieties that grow in situations from sea level to more than 10,000 feet, from swamp to desert, from the Tropics to the Arctic. Among the pines are stately forest giants, small very ordinary trees, and even some shrubs no taller than a man. Finally, pine species supply a great part of the construction lumber for this country and are notable timber producers throughout the world. Their wide range of size and of wood quality and their adaptability to a great variety of ecological conditions (figs. 2 and 3) make the pines suitable for genetic work. Plant breeding is dependent on variability of the experimental material for best results.

[1] During these years the board of trustees guided the policies of the institute. After 1935, when the institute became public property, the board served as an advisory council during the period of readjustment; its members were: E. B. Babcock, Berkeley, Calif.; Swift Berry, Camino, Calif.; Earle H. Clapp, Washington, D. C.; William Crocker, Yonkers, N. Y.; James G. Eddy, founder of institute, Medina, Wash.; David Fairchild, Coconut Grove, Fla.; H. S. Gilman; William B. Greeley, Seattle, Wash.; Ralph S. Hosmer, Ithaca, N. Y.; James A. Irving, Placerville, Calif.; Donald F. Jones, New Haven, Conn.; T. H. Morgan; Walter Mulford, Berkeley, Calif.; A. Stanwood Murphy, San Francisco, Calif.; Donzel Stoney; Robert E. Swain, Stanford University, Calif.; Walter A. Starr, San Francisco, Calif.; and Donald B. Tresidder, Chairman, Stanford University, Calif.

F–437396

FIGURE 2.—Their adaptability makes the pines good subjects for genetic improvement. This huge sugar pine may contain enough lumber for two small homes, but it could not survive as severe growing conditions as the whitebark pine shown in figure 3.

Although the pine tree produces good lumber, it does not produce it as rapidly as man needs it. The "virgin timber" of old mature trees may be from 250 to 500 years old. In the West second-growth timber is now being harvested and used when from 50 to 90 years of age and from 20 to 40 inches in diameter at breast height. Perhaps the tree breeders' most im-

F–331226

FIGURE 3.—Whitebark pine often marks timber line in the mountains.

portant contribution to forestry would be to reduce the number of years needed to produce trees of harvest size. Therefore, the institute adopted the production of faster growing pines as its primary objective. Trees with such other desirable features as wood quality, resistance to insects and diseases, and adaptability to particular locations could be selected from fast-growing strains. or desirable traits could be bred into trees by hybridizing.

Seed-Tree Studies

Of several methods available to the plant breeder, selection, the oldest and most widely used method, was chosen for the first intensive trials. A series of "progeny" tests was inaugurated by Lloyd Austin, assisted by A. R. Liddicoet. Progeny tests are those which judge the value of a forest tree as a possible seed parent by the quality of its offspring. A few dozen to a hundred or more seedlings grown from the seed of a tree are considered necessary for reliable judgment as to its value as a parent tree. In 1929, a planting was made of ponderosa pine seeds collected from the principal geographic localities where this species grows, from South Dakota to British Columbia and southward to Arizona and California. Revealing a tremendous variation of growth in strains from the different localities, records of this planting, presently being analyzed by R. H. Weidman, may aid in the selection of seed that will produce better trees wherever ponderosa pine is planted.

Other smaller tests were begun from time to time until 1937 when an experiment was set up to test 729 individual seed trees of ponderosa pine. This test was a hunt for seed trees that would consistently produce rapidly growing offspring for use in forest planting. A few more years are needed before definite conclusions can be drawn from this test, but two facts are already apparent: (1) Maintaining experimental control is difficult, and (2) the costs of conducting such tests may be excessive when compared with the benefits to be expected from this method of pine breeding.

Although most of the funds and manpower of the institute were expended on progeny tests prior to 1940, other lines of investigation were started on a small scale. As early as 1927 attempts were made to hybridize different species of pines, but proper techniques had not been developed and with one exception those early crossings failed.

THE HYBRID PROGRAM

In 1940, it was decided that the progeny tests already under way were sufficient to demonstrate the possibilities of this method in pine breeding. Emphasis was therefore swung to hybridizing. During World War II work at the institute was curtailed, as staff members spent most of their time in special war work. Even so, the small amount of hybridizing done produced several promising pine hybrids. In this experimental breeding work, F. I. Righter and W. C. Cumming, assisted by A. R. Liddicoet, have demonstrated that the method is practical, that many pine species can be successfully crossed, and that the general character of pine hybrids is comparable to that of many other plant hybrids.

While it would be possible to attempt about 2,500 different crosses among the pines, only a dozen or so new crosses can be tried each season. The rest of the time and effort available is spent in making various checks, controls, and other operations. Successful crosses that appear interesting are repeated at least twice to verify past results. Unsuccessful crosses are also repeated to make certain that faulty technique, poor pollen, or other remediable circumstance was not responsible for the failure. When hybrids have shown particular promise in the nursery, larger scale pollinations than are done for experimental purposes are made to produce enough seed for field testing in several localities.

Because of the small number of trial crosses possible each season, their choice becomes of great importance in the breeding program. New crosses

to be tried are selected primarily as the result of phylogenetic studies, which reveal how the various species are related. These studies examine such features of relationship as morphology, chemical characteristics of the oleoresin when available, or physiological adaptation, distribution, and cross-ability of different species as shown by previous tests. One small, well-marked group called the closed-cone pines is being studied intensively to determine patterns of behavior of species within a group. Clues disclosed by this study are useful in predicting the potentialities and behavior of species belonging to other relationship groups too large for detailed study. By this means W. P. Stockwell plans each season's program of new crosses, the object being to select for trial those species that seem most likely to yield hybrids of practical value.

Successful Crosses Made

Hybrid plants in general are expected to be intermediate between the parents with respect to any particular character (fig. 4). This is true of

FIGURE 4.—Characteristics of Coulter pine (left) and Jeffrey pine (right) are apparent in the center hybrid cone. All three cones are immature.

most hybrid pines. Such hybrids can be used to extend the range and increase the growth rate of the slower-growing parent where vigor is the objective of the breeding program. For instance, the knobcone pine is a small, thin-foliaged, frost-resistant tree of the Coast Ranges and Sierra Nevada foothills of California. Monterey pine is a rapid-growing, heavy-foliaged, frost-tender species of the central California coast. The hybrid between these species grows almost as fast as Monterey pine, has withstood a temperature of 16° F., and has dense foliage much like that of Monterey pine. It should be useful as a fast-growing ornamental or for windbreaks and erosion control in localities somewhat too cold for Monterey pine.

Other pine hybrids are of greater interest to other localities than to California. The hybrid between jack pine of the Lake States and lodgepole pine of the Rockies and Sierra Nevada has the good form of the lodgepole pine and a growth rate almost equal to that of jack pine. Since it has advantages over both parents, it should be of value in the Lake States and in the Rocky Mountains.

The ponderosa pine of the Sierra Nevada when crossed with scopulorum pine of the Rockies produces a hybrid equal to ponderosa in growth rate at 4 years. Although starting slow, after the fifth year it exceeds the ponderosa pine in height. This hybrid presumably has some of the hardiness of the

scopulorum parent. It is a prospect for trial in the Great Basin area and eastward.

When Apache pine of southern Arizona is crossed with ponderosa pine, the hybrid at 3 years approximates the height of ponderosa at the same age. At 4 years, the hybrid equals or slightly exceeds the ponderosa in height, and has the heaviest stem and most extensive root system of any pine seedlings examined at this station.

Another promising hybrid is a backcross. This is produced by placing pollen of a hybrid between Jeffrey and Coulter pines on the conelets of one of the parents, Jeffrey pine. This vigorous hybrid (fig. 5) is resistant to resin midge and the pine reproduction weevil, both serious pine plantation pests, and it should be hardy to cold throughout much of the ponderosa pine belt. Although Coulter pine does not produce the best of lumber, it is hoped that the hybrid will inherit good lumber quality from the Jeffrey pine, which is an excellent timber species. This is probably the first hybrid that will be produced in quantities sufficient for field trials of a hundred or more acres.

While hybrid plants in general are expected to be intermediate in character between the parents, occasionally the hybrid excels both parents in growth rate, fruit yield, or other characters. Some white pines have shown this hybrid vigor. When pollen of the eastern white pine is used to fertilize conelets of western white pine, the seeds produce hybrids (fig. 6) that are twice as tall and three times as heavy as the best parent when grown at Placerville. Essentially the same results are obtained by crossing the Himalayan white pine with both the eastern and the western white pines of America. These three hybrid white pines are prospects for planting throughout the country where white pines are needed.

F–435426

FIGURE 5.—Jeffrey pine, on the left, is a slow-growing tree with good-quality wood. Coulter pine, right, grows rapidly but has rather poor-quality wood. In the center is a backcross of Jeffrey and Coulter pine that is rapid growing and, it is hoped, will have satisfactory wood. All three are 4 years old. (The measuring stick is one meter (3.28 feet) high.)

F–435426

FIGURE 6.—Sometimes pine hybrids grow faster than seedlings from either parent. In the center is the hybrid of eastern and western white pines. To the left is western white pine and to the right eastern white pine. All three are 4½ years old and average size for the lot.

Another white pine project of somewhat different nature is under way at the Institute of Forest Genetics. The Balkan white pine (*Pinus peuce*) is a tree of rather poor timber form, but it is considered to be highly resistant to the destructive white pine blister rust. Hybrids between this species and the eastern white pine of America have shown a high degree of resistance to blister rust when grown in the Royal Botanical Gardens of Denmark as reported by Dr. C. Syrach-Larsen. Pollen of these hybrids and of Balkan white pine are now being used at Placerville in an attempt to produce a timber tree of good form that is resistant to blister rust. If the work is successful, it will be of importance in saving the white pine industry of this country, which at present suffers serious loss of timber from the blister rust disease.

Hybrid Plantations Planned

In 1946 the first step was made toward trial of some of the more promising hybrids by large-scale plantings in forest areas. Studies of methods for quantity production of hybrid seeds were begun by J. W. Duffield. The ultimate aim is mass production of hybrid trees for use in reforestation work. It is not expected, however, that hybrid seed can be made available for general planting in the immediate future. The pines differ from most other plants in that two summers must intervene between pollination and seed ripening. From 1 to 3 additional years are required to bring the young trees to a size suitable for outplanting. In all, 4 to 10 years may pass from

the time of pollination to the time when preliminary judgment can be made on the growth rate and general value of new pine strains under plantation conditions. Even more time may be needed to decide if the hybrids will be satisfactory for timber production.

In order to put the hybrid pines to practical use more quickly, F. I. Righter has suggested that they be interplanted among regular planting stock or among the natural reproduction on cut-over forest lands. If the hybrid proves to be unsuited to the situation, it will be crowded out; but if it proves to be superior to the regular planting stock or native seedlings, it will form the mature stand of trees. By this method it may be possible to test some of the hybrids under field conditions without great risk of failure to produce a timber crop. At the same time these plantings can take advantage of any good qualities the hybrids may develop.

F-353701

FIGURE 7.—Cuttings are used to propagate rare material or to produce trees of identical heredity. This cutting of ponderosa pine has developed an extensive root system in 1 year.

RELATED RESEARCH

While the production of hybrids has been the primary objective of the work for several years, other research activities have been necessary to make hybrid production possible, or to otherwise facilitate the program. These activities cover a wide range of subjects.

Elevation Effects

In 1939 stations at 750, 2,700, and 6,000 feet were planted with seedlings of the same age from parent trees selected to sample the Sierra Nevada ponderosa pine forest's range in elevation. Seedlings from each parent were planted at each station. Information yielded by this test will be useful in determining the best elevation at which to collect seed for planting on particular sites. Hybrid strains produced at the institute should receive the same kind of tests to discover their climatic adaptability.

Cuttings and Grafting

Propagation of pines by cuttings and grafting is desirable at times in research work. Since little published information on this subject was avail-

F-382522

FIGURE 8.—This scion grafted on ponderosa pine stock growing in a pot illustrates one method of propagating rare material. Pine scions shipped from several parts of the United States have been successfully grafted at the institute.

able, experimentation was started soon after establishment of the institute. Methods were devised for rooting cuttings (figs. 7 and 9) and for grafting (fig. 8). N. T. Mirov, who is assisted by E. F. Kimbrough in this and other physiological work, learned that not only branchlets but even needle bundles could be used for cuttings and for scions in grafting. By use of these methods portions of valuable trees from other localities may be propagated. or as many genetically identical offspring as may be needed can be had from any particular tree.

Seed Variation

A third investigation sought ways of judging the inherent vigor of young trees still in the nursery. Several factors other than inherent capacity to grow fast affect the size of seedling trees for several years. Differences in

F-447362

FIGURE 9.—Rapid growth of trees propagated from cuttings is demonstrated by the center Monterey pine. It has grown 25 feet in 7 years since the cutting was planted.

time of germination and in seed size are most important. There is often a difference of a month or two between the germination of the earliest and the latest seed. When seeds are late to germinate, the young trees have a shorter growing season the first year and are, therefore, smaller. It may take several years for the tree to overcome this initial handicap. By reference to pub-

lished work on other plant species and by experimentation, schedules were developed for chilling pine seeds that make it possible to germinate all seeds within a 3-day period after planting. Then, too, the stimulus given by the food supply in large seeds may mask the seedlings' true growth rate for 2 or 3 years. To overcome this difficulty, all seeds for experimental use are weighed and segregated into classes so that the growth of trees from seed of like weight may be compared.

Pollen Storage

A fourth study at the institute has resulted in techniques for storing pollen, one of the most critical steps in the pine hybridizing program.

Pine trees bear primitive flowers of the type known to botanists as the strobilus. Male strobili, or pollen-bearing catkins, and female strobili, or

F-336100

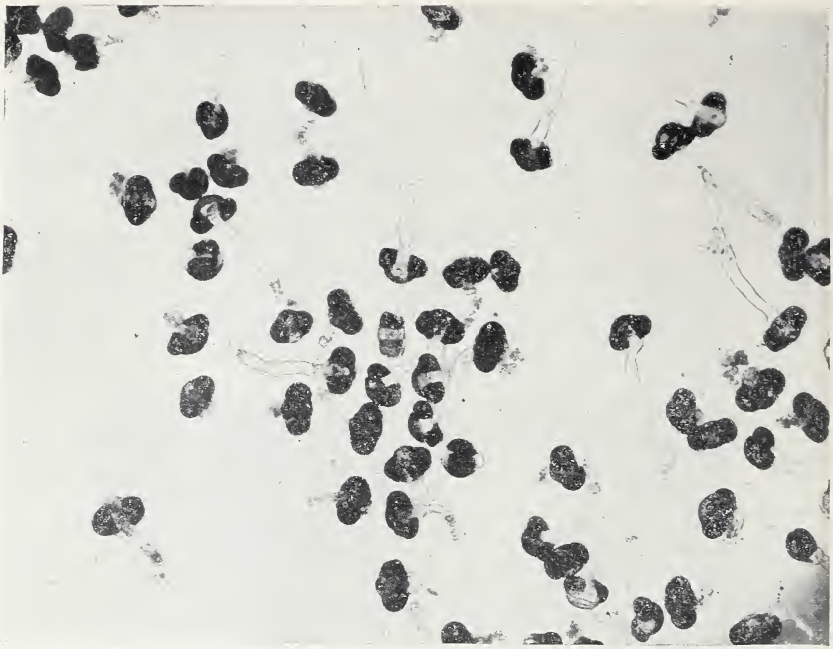
FIGURE 10.—In the center of this magnified pollen grain are clustered the 12 pairs of chromosomes characteristic of pines. Genes, which are determiners of hereditary characters, are located in the chromosomes. (Preparation by D. A. Johansen and E. A. Larson.)

seed-bearing cones, are borne on each tree. In tree breeding work it is sometimes necessary to hold pollen for a year or more to complete cross pollination of the trees being studied. But pollen (figs. 10 and 11) is very delicate and under ordinary conditions of storage soon dies.

The storage problem was attacked by setting up a series of tests to determine the best conditions of moisture and temperature for maintaining pine pollen in viable state for long periods. Under the best conditions discovered, pine pollen remains alive after several years of storage.

OUTLOOK

In plant-breeding research, an accumulation of experience and intimate knowledge of the plants under investigation is needed. Patience on the part of the worker and the promoter is essential because years may be necessary to acquire the information that forms the background for successful work. Once established, however, such a background enables the worker to be increasingly effective. His ability to judge what is possible with his experi-



F-434693

FIGURE 11.—Pollen grains germinating in a testing dish. If pollen is viable, a tube grows—as shown in the photograph—from the central part of a pollen grain to the archegonium and its egg cell, completing the fertilization process. (Magnified 68 times.)

mental material increases, research progress is accelerated, and worth-while results come more frequently. This sequence of events is evident in the history of the work at Placerville.

Most of the pine species of the world have been assembled in the Eddy Arboretum of the institute, where they form a reservoir of breeding material. Nearly all have reached fruiting age and may be used for experimental if not for large-scale hybridization. Results in the years 1941-46 indicate new and promising hybrids may be expected in each year's nursery. Propagation and breeding techniques are sufficiently developed to give assurance to the breeder.

The United States Forest Service looks toward the third decade of pine breeding with optimism. There is confident hope that this work will aid in increasing the Nation's timber supply and in justifying the faith of those who have patiently supported the work through the first 20 years.

RECORD
OCT 6 1948
U. S. DEPARTMENT OF AGRICULTURE

U. S. GOVERNMENT PRINTING OFFICE: 1948

For sale by the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.
Price 10 cents